AN IMPLANT TO BE IMPLANTED IN BONE TISSUE OR IN BONE TISSUE SUPPLEMENTED WITH BONE SUBSTITUTE MATERIAL

Field of the invention

The invention lies in the field of medical technology and relates to an implant which is implanted in human or animal bone tissue or in bone tissue supplemented with bone substitute material.

The implant according to the invention is e.g. a dental implant which, assuming the function of a natural tooth root, is implanted into a jawbone, and for fastening an artificial tooth crown, a bridge or a dental prosthesis e.g. comprises at its proximal end a fixation location which after implantation is located in the region of the bone surface. The dental implant may represent a complete tooth replacement, that is to say may also have a crown region in addition to a root region to be implanted. The implant may also have a different function and may be suitable for implantation in another human or animal bone. Generally speaking, the implant serves for connecting a bone part with another tissue part, in particular with another bone part, or with an artificial part, which artificial part may support or replace a bone part (e.g. artificial joint) or a tooth or it may be a therapeutic auxiliary device (e.g. drug release device, drainage device or stimulating device for electric or chemical stimulation). The implant may further be such therapeutic auxiliary device itself or it may serve for replacing missing bone tissue or possibly bone tissue to be regenerated (e.g. after removal of a tumor) or it may be an augmentation element for augmenting natural bone in a desired way.

Background of the invention

Fixation of tooth replacement structures (individual teeth, groups of teeth, part-prostheses or complete prostheses) based on the above mentioned dental implants with fixation locations is according to the state of the art e.g. realized in the following steps: after removal of the natural tooth root one waits until naturally regenerated bone tissue fills the opening in the jawbone. In the region of the regenerated bone tissue an opening adapted to the implant is created. The implant is positioned in the opening, wherein the opening is deep enough for housing the complete implant, which therefore does not protrude beyond the opening. An inner thread defining the fixation location at the proximal face of the implant is closed with a cover screw. The gum is closed over the cover screw and one waits until the bone tissue has ingrown with the

implant and by way of this has a stability (secondary stability) sufficient for the loading to be expected. Then, in a further step, the gum is opened over the implant and the cover screw is replaced by a distancer, wherein the distancer projects beyond the gum. Only when the gum around the distancer is healed is the tooth replacement structure fastened on the implant. The briefly described procedure entails a treatment duration of twelve to eighteen months for the patient, of which two to three months fall in the time between the implantation and a point in time at which the bone tissue has grown around the implant or the implant is ingrown in the bone tissue such that the implant has sufficient stability for loading.

The first waiting period (regeneration of bone tissue in an opening in the jawbone) may be avoided or shortened if implants are used which in their shape are adapted as exactly as possible to the original opening, as for example described in the publication US-6132214 (Suhonen et al.).

The dental implants according to the state of the art usually consist of pure titanium or of a titanium alloy. These materials exhibit a very good biological compatibility and there are various known surface designs which further improve osseo-integration. Very often the implants also comprise macroscopic structures which permit the bone tissue to grow into or through the implant. However, the stability of these known dental implants is only adequate for full loading after complete osseo-integration, i.e. only when they are intimately grown around by bone tissue or ingrown or intergrown with bone tissue (secondary stability). In osteoporotic or soft bone, as well as in poorly regenerating bone tissue, for example of older patients it may happen that no sufficient implant stability can be achieved.

The primary stability of the above-described dental implants, i.e. their stability directly after implantation, is greatly limited. For this reason the above mentioned waiting time is added between implantation and further build up. The primary stability of the mentioned implants varies according to implant form, but in most cases it is not sufficient for full loading. Pin-like implants with a thread are restrictedly loadable by tension and compression and possibly transverse forces, in particular when implanted such that at least one thread convolution lies in the region of the cortical part of the bone. They can hardly be loaded by torsion. Implants which do not have a round cross section, i.e. which are adapted to a natural tooth root, are more stable when loaded by torsion, but less stable when loaded by tension. The same applies to plate-like dental implants which may also comprise a plurality of fixation locations.

The un-sufficient loadability of known dental implants would, on loading immediately after implantation lead to movements between implant and bone tissue great enough for impeding or even preventing osseo-integration. However, immediate loading of implants is not only desirable in order to shorten the treatment duration, but also to avoid atrophy of the jawbone

due to non-loading, i.e. to promote osseo-integration by way of micro-movements (not exceeding a physiological measure) between implant and bone tissue which can only be achieved by loading a stable implant.

The primary stability, in particular the ability to be loaded in tension and compression is increased for pin-like implants according to the state of the art by way of a suitably formed threads (US-3499222), by spread-out elements (e.g. US-5766009, EP-1184006) or by collar-like elements. Anchor-like implants in particular used for fastening wires or sutures are equipped with barb-like surface structures (US-4360343) for increasing the primary and secondary stability regarding tension loading. However, these improvements neither permit loading of the implants directly after implantation.

Brief description of the invention

It is therefore the object of the invention to provide an implant suitable for implantation in bone tissue or in bone tissue being supplemented by bone substitute material, which implant has a very good primary stability, such that it is for instance able to be loaded immediately after implantation, which implant however is equipped for further clinical functions, e.g. for osseo-integration, for passage of particles or molecules into or out of the implant (delivery or drainage), for electric or chemical stimulation etc. and this also immediately after implantation. The further clinical functions of the implant are not to suffer clinically relevant restriction by the wanted primary stability. If the implant has e.g. a load bearing function, i.e. if it is e.g. a dental implant, it is to be able to be loaded as unlimited as possible immediately after implantation or at least significantly earlier after implantation than known such implants, wherein however osseo-integration (further clinical function) remains substantially unhindered, i.e. begins immediately after implantation such that the above mentioned positive effects on osseo-integration effected by early loading can be fully exploited. Furthermore, neither the implant according to the invention nor its implantation is to be significantly more complicated than is the case for implants according to the state of the art.

The surfaces of the implant according to the invention, which are to come into contact with bone tissue or which are for instance to be grown around by bone tissue or are to be intergrown by bone tissue comprise regions of a first type and regions of a second type different from the surface regions of the first type.

The surface regions of the first type are equipped in a per se known manner for one or more than one predetermined clinical function. Examples of such clinical functions are promotion or at least enablement of osseointegration for a good secondary stability, delivery of

therapeutically effective compounds into tissue surrounding the implant, removal of unwanted compounds from tissue surrounding the implant (drainage) or electric or chemical stimulation of tissue surrounding the implant.

For e.g. an implant with a load bearing function, the surface regions of the first type comprise e.g. structures suitable for a stable ingrowth or through growth with vital bone tissue and they are at least regarding osseo-integration biologically active. Furthermore or in addition compounds having e.g. osseo-integrative, inflammation-suppressing, infection-combating, growth-promoting effects may be delivered through the surface regions of the first type or these surfaces may be equipped for passage of therapeutically effective stimulating impulses.

The surface regions of the first type are e.g. biologically compatible surfaces (e.g. made of titanium) and they can be formed to have structures which are suitable for bone tissue ingrowth. Such surfaces may further be coated with a material comprising calcium phosphate, they may be modified e.g. by phosphonates or peptide sequences and/or they may comprise gels or polymers containing e.g. growth factors.

The surface regions of the second type are designed for producing the primary stability. For this purpose these regions comprise a material which can be liquefied by mechanical oscillation, i.e. a material having thermoplastic properties (thermoplast or composite material comprising a thermoplastic component) or a thixotropic cement, wherein the liquefiable material is liquefied and pressed into unevennesses, pores or suitably produced geometries of the bone tissue surrounding the implant by application of mechanical oscillation (e.g. ultrasonic oscillation) during implantation.

The material constituting the surface regions of the second type forms part of the outer surface of the implant already before implantation or it is located on the inside of the implant and during implantation it is pressed in a liquefied state through corresponding openings to the outer surface of the implant, where it creates in situ the surface regions of the second type.

For the liquefied material of the surface regions of the second type to be able to be pressed into the bone tissue during implantation, the surface regions of the second type are arranged in a manner such that they come into contact with the bone tissue on positioning the implant in the bone. This means that the surface regions of the second type project for example at least locally beyond the surface regions of the first type or they are located at implant edges, projections, etc. For implants containing the material forming the surface regions of the second type inside, openings for pressing out the liquefiable material are arranged accordingly.

The surface regions of the two types are arranged and the liquefiable material and/or liquefaction are dimensioned in a manner such that the surface regions of the second type remain as free as possible of the liquefied material. This guarantees that the further clinical functions of the first type regions are not hindered or are hindered only to a clinically acceptable degree, even immediately after implantation. Therewith it is e.g. achieved that osseo-integration of surface regions of the first type is not only not hindered but is also not delayed and therefore starts immediately after implantation.

For implants which during implantation are moved relative to the bone tissue in an implantation direction, separation of the two types of surface regions is achieved by arranging the two types of surface regions next to one another and parallel to the implantation direction.

In the same way as known implants, the implant according to the invention is implanted in an opening specifically created for the implant possibly in beforehand regenerated bone tissue e.g. of the jawbone, wherein this opening may accommodate the whole implant (root region) or wherein the implant in a self-cutting manner may be forced deeper than the opening into the bone tissue. The opening may for example only concern the cortical bone layer or, with a suitable design of the implant, it may be completely omitted. The implant according to the invention may also in the sense of a replica have a shape adapted to an irregular form of a bone cavity, e.g. the shape of a removed, natural tooth root and may be implanted directly into this cavity.

The implant according to the invention is e.g. a dental implant having the shape of a pin or of a natural tooth root and having at its proximal end a fixation location (e.g. pocket hole with an inner thread or location at which the dental surgeon may create such a pocket hole) or an artificial crown region. At its distal end it may be formed chisel-shaped and/or be provided with lateral self-cutting or grooving structures. It may furthermore be plate-shaped, disk-shaped or blade-shaped and comprise one or more fixation locations, or it may have the shape of an anchor on which for example a wire or a suture can be fastened.

The implant according to the invention is of one piece and comprises the above-defined, different surface regions which for example consist of different materials, or it contains the liquefiable material inside and comprises openings through which the material when liquefied is pressed to the outer side of the implant. The implant may also be two-piece or multi-piece, wherein the surgeon combines two or more parts of various materials to form the implant.

For implantation, the implant according to the invention is positioned in the opening in the bone (or bone tissue supplemented with bone substitute material), e.g. in a jawbone, and then mechanical oscillation is applied to it, for example ultrasound, and simultaneously it is pressed

against the bone. This causes at least part of the liquefiable material to be liquefied and pressed into pores, surface unevennesses and/or created geometries of the surrounding bone tissue, where after solidification it forms a positive-fit connection between the implant and the surrounding bone tissue or possibly bone substitute material. Depending on the implant design, the implant may also be advanced in the bone tissue (implantation direction) simultaneously to liquefaction.

For applying mechanical oscillation to the positioned implant, the sonotrode of an ultrasound apparatus is for example placed onto the proximal end of the implant. Experiments show that good results are achieved with a power of 0.2 to 20 W per square millimeters active surface. The frequency of the oscillations is between 2 and 200 kHz.

Implants according to the invention and having a load bearing function (e.g. dental implants) comprise e.g. a central implant part carrying the surface regions of the first type and being made e.g. of metal (e.g. steel, titanium, cobalt/chromium alloy), of a ceramic or glass-like material (e.g. aluminum oxide, zirconium oxide, ceramic or glass of calcium phosphate), of a thermoset or high-temperature thermoplastic polymers (Polyether arylketones, Polyfluoro- or polychloroethylenes, polyether imides, polyether sulphones, polyvinylchloride, polyurthanes, polysulphones, polyesters) or of a composite material (e.g. high-temperature thermoplast reinforced with carbon fibers). Such implants also comprise a peripheral implant part of the liquefiable material, for example of a material with thermoplastic properties. The liquefiable material may also be placed on the inside of a hollow, central implant part, wherein the walling of the central implant part has through openings through which the liquefied material is pressed under the influence of the mechanical oscillation, in order to form surface regions of the second type on the outside of the walling. The implant parts may be connected to one another on the part of the manufacturer or only be brought into connection with one another by the surgeon directly before or during implantation.

Implants according to the invention which have no relevant load bearing function (e.g. implants having a delivery function, a drainage function or a stimulating function) may also comprise a central implant part and a peripheral implant part, the peripheral implant part consisting at least partly of the liquefiable material, wherein the mechanical stability (load bearing function), which is necessary for implantation may be taken over by the peripheral implant part, the central implant part having but very little mechanical stability. Such a central implant part is e.g. a permeable container e.g. of porous calcium phosphate or of an other bone substitute material having little mechanical stability or of a thin membrane, wherein delivery or drainage or stimulation takes place through the container wall. The central implant part may also be a body of e.g. porous calcium phosphate or of another bone substitute material and have the function of initiating or assisting formation of missing or additionally desired bone tissue. It is possible to provide the liquefiable material on the inside of the central implant part and press it

when liquefied through corresponding openings to the outer surface of the central implant part, even if the latter implant part has little mechanical stability.

The implant according to the invention may also consist of one only material which is able at the same time to fulfil the demands with regard to the mechanical strength of the implant and possibly of a fixation location, the demands set by the further clinical functions of the surface regions of the first type (e.g. biological integration or secondary stabilization respectively) and the demand of the liquifiability by mechanical oscillation. As the case may be, in various regions of the implant the one material may be filled to varying degrees (e.g. with fibers, whiskers or particles) or it may be filled with different materials in different regions. In this case too, a suitable design of the surface regions to be integrated in the bone tissue must ensure that on implantation, the surface regions of the second type or the liquefied material respectively comes into contact in particular with the bone tissue and that the liquefied material is not or only to a clinically irrelevant degree carried onto the surface regions of the first type.

For implants with surface regions equipped for osseo-integration, the liquefiable material is advantageously at least partly biologically degradable (resorbable) so that the stability function (primary stability) of the positive fit between the implant and the bone tissue is gradually taken over by the stability function (secondary stability) of the osseo-integration, which advantageously increases to the same degree as the liquefiable material is resorbed, i.e. the primary stability decreases. In particular in the case of osteoporotic bone tissue or poorly regenerating bone tissue it may be advantageous to permanently retain the primary stabilization as a supplement to the secondary stabilization, i.e. to use a non-resorbable, liquefiable material, which may also be equipped for good biological integration (secondary osseo-integration).

For implants with other than load bearing functions, the liquefiable material is advantageously at least partly resorbable, if the implant is to be removed from the bone tissue or to be completely replaced by bone tissue. If the primary stability is to be retained, the liquefiable material is not resorbable or only partly resorbable.

Resorbable polymers e.g. based on lactic acid and/or glycolic acid (PLA, PLLA, PGA, PLGA etc.) or polyhydroxyalkanoates (PHA), polycaprolactones (PCL), polysaccharides, polydioxanones (PD), polyanhydrides, polypeptides or corresponding copolymers or blended polymers or composite materials containing the mentioned polymers as components are suitable as resorbable liquefiable materials. Thermoplasts such as for example polyolefins, polyacrylates, polymetacrylates, polycarbonates, polyamides, polyesters, polyurethanes, polysulphones, polyaryl ketones, polyimides, polyphenyl sulphides or liquid crystal polymers (LCPS), polyacetals, halogenated polymers, in particular halogenated polyoelefins, polyphenylene sulphides, polysulphones, polyethers or corresponding copolymers or blended polymers or

composite materials containing the mentioned polymers as components are suitable as non-resorbable polymers. Applicable thixotropic systems are resorbable, partly resorbable or non-resorbable polymeric, ceramic or hydraulic cements (e.g. Norian® of Synthes or Sulfix® of Centerpulse).

The liquefiable material may contain foreign phases or compounds serving further functions. In particular, the liquefiable material may be strengthened by admixing fibers or whiskers (e.g. of calcium phosphate ceramics or glasses) and such represent a composite material. The liquefiable material may further contain components which expand or dissolve (create pores) in situ (e.g. polyesters, polysaccharides, hydrogels, sodium phosphates) or compounds to be released in situ and having a therapeutic effect, e.g. promotion of healing and regeneration (e.g. growth factors, antibiotics, inflammation inhibitors or buffers such as sodium phosphate against adverse effects of acidic decomposition). If the liquefiable material is resorbable, release of such compounds is delayed.

The implant part not comprising the liquefiable material is not resorbable, if the implant is to remain in the patient's body or if it is to be removed surgically. However this implant part may also be made at least partly of a resorbable material, which after implantation is gradually replaced by vital tissue.

The design of the implant and the selection of the liquefiable material are to be matched to one another in a manner such that the strength of the positive fit is sufficient for the expected loading, and in a manner such that liquefaction entails a reasonable, that is to say, a low as possible heat release. If liquefiable materials with a relatively high softening temperature are used, it is advantageous to ensure that the implant as a whole (including liquefiable material) conducts the mechanical oscillations as a resonator so that the liquefiable material is liquefied in the surface regions of the second type only very locally, e.g. only in regions of suitably provided energy directors. In this manner the released quantity of heat can be kept to within an acceptable scope. In particular, when using a material with a relatively low softening temperature or a material being liquefiable without release of heat (e.g. thixotropic cements), liquefaction may also be effected in the inside of the liquefiable material (by large damping of the exciting oscillation) or at contact locations between the central and peripheral implant part.

The heat burden on the tissue during implantation may be reduced even further by designing the central implant part to comprise materials with a large heat-conducting capability and/or a large thermal capacity (e.g. silicon carbide) and, as the case may be, to comprise cooling channels through which a cooling medium is flown.

Brief description of the drawings

Exemplary embodiments of the implant according to the invention are described in detail by way of the following Figures, wherein:

Figs. 1, 2A, 2B, 2C show three first exemplary embodiments of a substantially pin-shaped implant according to the invention (e.g. dental implant), the implants comprising a central and a peripheral implant part, (Fig. 1: side view, Figs. 2A to 2C: cross sections);

Fig. 3 shows a second exemplary embodiment of the implant according to the invention (e.g. dental implant), the implant comprising a central and a peripheral implant part, wherein the shape of the implant is adapted to an existing cavity in a bone (e.g. cavity caused by removal of a natural tooth root from a jawbone);

Figs. 4 and 5 show two further embodiments of the implant according to the invention (e.g. dental implant), the implant comprising a central and a peripheral implant part, wherein the central implant part is adapted to an existing cavity in a bone (e.g. is an imitation of a natural tooth root) and is designed to be self-cutting or grooving (cross section);

Fig. 6 shows a further essentially pin-shaped embodiment of an implant according to the invention (e.g. dental implant), the implant comprising a central and a peripheral implant part (side view);

Figs. 7 and 8 show an exemplary embodiment of an implant according to the invention, the implant being shaped as an anchor (Fig. 7: side view; Fig. 8: cross section);

Figs. 9 and 10 show an exemplary embodiment of a plate-shaped, disk-shaped or blade-shaped implant according to the invention (e.g. dental implant with two fixation locations) as a side view (Fig. 9) and a plan view (Fig. 10);

Figs. 11 and 12 show an exemplary embodiment of a substantially pin-shaped implant according to the invention (e.g. dental implant), the implant comprising a hollow central implant part (Fig. 11: longitudinal section; Fig. 12: plan view).

Fig. 13 shows an exemplary embodiment of the implant according to the invention, the implant comprising a central implant part with no relevant mechanical stability;

Fig. 14 shows an augmentation element as a further example of the implant according to the invention;

Figs. 15 and 16 (A, B and C of each) show two embodiments of implants serving for connecting two spinal vertebrae, in three dimensional illustrations (Figs. 15A and 16A), during implantation between the two vertebrae in a side view (Figs. 15B and 16B), and when implanted as a front view (Figs 15C and 16C).

Detailed description of preferred embodiments of the invention

Figures 1 and 2A to 2C show an exemplary, pin-shaped embodiment of the implant according to the invention, which implant has a load bearing function and therefore is e.g. a dental implant or an orthopedic implant serving e.g. for stabilizing a bone fracture or for fixing a support plate or as a shaft of an artificial joint part (e.g. hip, knee, shoulder or finger joint). The implant comprises a central implant part 1 and a peripheral implant part 2, wherein the central implant part comprises at its proximal end e.g. a fixation location 3 (e.g. pocket hole with inner thread or location at which a surgeon may create such a pocket hole). The distal implant end is e.g. designed chisel-shaped for a self-cutting effect. The implant may also, as illustrated in the cross section according to Fig. 2C, comprise axially extending, self-cutting or grooving elements 9. The central implant part 1 comprises surface regions 4 of the first type (e.g. with osseo-integrative, inflammation-inhibiting, infection-combating and/or growth-promoting properties) extending parallel to the implantation direction A. Between the surface regions 4 of the first type, the implant comprises surfaces which are suitable for connection to the peripheral implant part 2. The connection between the peripheral implant part 2 and the central implant part may be an adhesive connection 5 (Fig. 2A) or a positive fit connection, e.g. individual grooves 5' (Figs. 2A and 2C) with a narrowed opening slot or surfaces 5" with a multitude of openings or grooves (Fig. 2B). The peripheral implant part 2 comprises fingers 6 which for example fit into the grooves 5' or onto the surface regions 5" and which form at least part of the surface regions 8 of the second type.

As seen in Figs. 2A to 2C, the invention does not set any conditions on the cross section of the pin-shaped implants so that this may be selected depending on the function. Therefore, cross sections other than those shown in the three Figs. 2A to 2C are conceivable, for example a central implant part with a round cross section and fingers 6 seated thereon, as shown in Fig. 2A.

The implant illustrated in Fig. 2C may in particular be driven into the bone tissue for example in a largely self-cutting manner. For preventing the liquefied material from being driven onto the surface regions 4 of the first type, the surface regions of the first and of the second type (4 and 8) extend next to one another and parallel to the implantation direction A. In the proximal region where the implantation path is only short, the fingers 6 may open out into a ring 6' extending around the central implant part 1 and advantageously held in a groove of the central implant part. The ring 6' not only groups the fingers 6 together into a coherent, peripheral implant part 2 which is advantageous for easy connection of the two parts possibly by the surgeon, but also constitutes a means for intimate primary stabilisation between the implant and the cortical bone tissue in particular against tension and torsion. Where appropriate, a thread or a similar structure is created in the cortical bone so that the ring 6' can be connected to this relatively compact bone layer by a positive fit.

For an implant to be positioned in a deeper opening and not to be displaced or only slightly during oscillation, the surface regions of the first and second type may be arranged differently. The surface regions 8 of the second type may form instead of fingers 6 e.g. a pattern of points or intersecting lines. The arrangement of the surface regions 8 of the second type is thus to be adapted to the manner of implantation. Furthermore, the arrangement of the second type surface regions is to be adapted to the primary stability to be achieved by the liquefied material, i.e. the primary stability which cannot be achieved by the implant shape.

The two implant parts 1 and 2 of the implants shown in Figs. 1 and 2A to 2C may be connected to one another by the manufacturer. The peripheral implant part 2 may for example be manufactured by injection moulding directly on the central implant part 1. The two implant parts 1 and 2 may also be manufactured separately and be joined together by the surgeon not until directly before the implantation. In such a case it is advantageous to realize the positive-fit or adhesive connection between the two materials during the implantation in that the material of the peripheral implant part 2 is liquefied and for example is pressed into openings or grooves according to Fig. 2B of the central implant part. For this it may be necessary to provide the inner side of the peripheral implant part 2 or the corresponding surface of the central implant part 1 with energy directors.

The advantage of the joining-together by the surgeon lies in the fact that the two parts can be sterilised separately, i.e. possibly using different methods being adapted to the various functionalities of the parts. Sterilization of the whole implant is then not necessary. The joining-together just before implantation allows the manufacturer to make available a set of central implant parts differing from one another for example with respect to length and diameter and peripheral implant parts differing for example with respect to material or finger thickness, so that

the surgeon may himself put together a suitable implant exactly for the case in question (greater variability at lower number of components).

For implanting the pin-shaped implants according to Figs. 1 and 2A to 2C an implantation device (e.g. sonotrode of an ultrasonic device) is used , which device has a distal end substantially adapted to the proximal face of the implant. If necessary, a coupling piece is introduced between sonotrode and implant. The oscillation energy is advantageously applied to the central implant part.

Figure 3 shows a dental implant according to the invention which in principle is designed in a similar way as the implant according to Fig. 1 but takes its shape not from the known pin-like or screw-like implants, but rather from a natural cavity in a bone, in the illustrated case from an natural tooth root. Between the surface regions 8 of the second type which are formed by the peripheral implant part 2, i.e. in the surface regions 4 of the first type, the central implant 1 is provided with structures permitting like a thread an improved anchoring in the regenerated bone tissue (secondary stability).

Figures 4 and 5 show in cross section two further embodiments of the implant according to the invention, which are suitable for being implanted in existing bone cavities, e.g. in a cavity created by removal of a natural tooth root. The implant is adapted to a specific cavity and comprises axially extending, self-cutting or grooving elements 9. The central implant part 1 of the two implants consists of a pin part 1.1 (load bearing part) which carries e.g. a fixation location 3 or an artificial tooth crown and a body part 1.2. The body part 1.2 is shaped ex situ in the sense of a replica e.g. using the removed tooth root, as e.g. described in the publication US-6132214 (Suhonen et al.), or in situ, i.e. in the corresponding cavity.

The body part 1.2 according to Fig. 4 forms the surface region 4 of the first type (e.g. with osseo-integrative, inflammation-inhibiting, infection-combating and/or growth promoting properties) and consists of an advantageously resorbable or partly resorbable bone substitute material (e.g. calcium phosphate, polylactide, non-resorbable polymer filled with calcium phosphate, combination system with reinforcing elements). The peripheral implant part 2 is limited to the self-cutting or grooving elements 9 into which for example pin-like parts of the liquefiable material are introduced.

The implant according to Fig. 4 may be implanted in two successive steps. Firstly the existing cavity is filled with a piece of a bone substitute material (body part 1.2). Then the pin part is implanted wherein the anchorage through the liquefiable material (peripheral implant part 2) may effect at least partly the bone substitute material. Such cases are illustrated in Fig. 4 by dash dot lines.

The body part 1.2 according to Fig. 5 is formed by a relatively thin and as flexible as possible layer of the liquefiable material, i.e. is surrounded by the peripheral implant part 2 which forms the surface of the second type. Instead of the thin layer, a membrane which is at least partly coated with the liquefiable material may also be provided. The axially extending, self-cutting or grooving elements 9 comprise the surfaces 4 of the first type. The body part 1.2 consists of a plastic, curable material, for example of a bone cement which may be cured by light, ultrasound or heat or of a hydraulic cement, which cement preferably has thixotropic properties. On introduction into the cavity, the body part 1.2 takes the shape of the cavity. On applying mechanical oscillations not only is the liquefiable material of the surface regions of the second type pressed into pores and unevennesses of the surrounding bone tissue but also the body part is adapted to the shape of the cavity and is possibly also cured. The liquefiable material is advantageously resorbable so that the primary stability created by the surface regions 8 of the second type is taken over by a secondary stability which is firstly caused by osseo-integration of the body part 1.2 and on resorption of the body part by osseo-integration of the pin part 1.1.

Implants according to Figs. 4 and 5 which are designed as dental implants may be implanted in the jawbone essentially directly after removal of a natural tooth root because their shape is adaptable to the cavity created by the removal. Thanks to the primary stability achieved by the surface regions 8 of the second type they may also be loaded immediately, thereby causing micro-movements with physiological measures accelerating osseo-integration in the surface regions of the first type of the body part 1.2 and later of the pin part 1.1. Such dental implants thus shorten the treatment time even more than the implants according to Figs. 1 to 3. The same is applicable for implants designed for implantation in other bones than jawbones.

Figure 6 shows a further, pin-like embodiment of the implant according to the invention (e.g. dental implant, implant for fixation of bone fractures, implants for fixing support plates, shaft of artificial joint), the implant comprising a central implant part 1 and a peripheral implant part 2. The central implant part 1 comprises through-openings and/or non-through openings 11 for intergrowth with bone tissue in which openings for example pins 12 of the liquefiable material are inserted projecting beyond the surface of the central implant part 1 and held firmly by a friction fit. The pins 12 form together the peripheral implant part 2, the ends of the pins projecting out of the openings 11 over the surfaces 8 of the second type.

Figures 7 and 8 show in a side view and in cross section an anchor-shaped embodiment of the implant according to the invention. The fixation location 3 of this embodiment is for example formed as an eyelet. The anchor has a per se known shape and comprises a slot running over its length, in which slot a pin of the liquefiable material (peripheral implant part 2) is arranged with a positive fit. The pin 13 projects on both sides beyond the surface of the anchor.

The anchor-shaped implant, as known such anchor implants, may comprise additional barbs 14 which on loading in tension are pressed into the bone tissue such supplementing the positive-fit anchoring by the peripheral implant part 2. However, such barbs or similar retention means are by no means necessary.

The design of the anchor edges as cutter blades simplifies implantation without the use of a suitable opening in the bone tissue or in an opening which only concerns the cortical bone.

Figures 9 and 10 show as a further exemplary embodiment of the implant according to the invention a plate-shaped, disk-shaped or blade-shaped dental implant which for example comprises two fixation locations 3 or two artificial tooth crowns and whose peripheral implant part 2 consists of a plurality of pin-like parts 13 which are positioned in through openings in the plate, disk or blade and in the region of the fixation locations in grooves of the central implant part.

The plate-, disk- or blade-shaped dental implants of which one example is shown in Figs. 9 and 10 are positioned in the jaw from the jaw ridge the same as pin-shaped dental implants during application of mechanical oscillation (implantation direction A, Fig. 9). However, they may also be implanted into the jawbone from the side (implantation direction A', Fig. 10), for which implantation a part of the jawbone is removed and re-positioned after implantation.

Plate-, disk- or blade-shaped implants are not applicable only in the dental field but also in the orthopedic field, for which they comprise suitably equipped proximal regions.

Figures 11 and 12 show a further pin-shaped embodiment of the implant according to the invention (e.g. dental implant or implant for orthopedic application) in a longitudinal section and as a plan view. The central implant part 1 is designed as a sleeve having an inner space 2', in which the liquefiable material is contained. The sleeve wall comprises through openings or slots 20 which for example are arranged in axial rows or extend axially. The implant is positioned in a bone cavity and an oscillating element 21 (sonotrode of an ultrasound apparatus) is placed onto the liquefiable material in the inner space 2' of the central implant part applying the oscillation to this material and simultaneously pressing it towards the distal implant end. By way of the oscillations the material is liquefied and by way of the pressure it is pressed through the openings or slots 20 into surface unevennesses and pores of the surrounding bone tissue, thereby creating the positive fit for primarily stabilizing the implant.

If the central implant part 1 is provided with a chisel-like, distal end as shown, the implant according to Figs. 11 and 12 can also be driven into the bone tissue (at least cancellous

bone) without the need of an opening. An annular sonotrode 22 is suitable for this. Sonotrode 21 is applied as soon as the implant has reached the predefined position in the bone.

In an implant according to Figs. 11 and 12 the peripheral implant part is actually created only when the implant is positioned in the bone tissue, i.e. it is created in situ.

The liquefiable material which is provided in the inner space 2' of the central implant part may be a thermoplastic material like liquefiable material arranged on the outside of a central implant part. Advantageously however, it is a polymer or hydraulic cement having thixotropic properties, which cement is curable after implantation by e.g. ultraviolet light, heat, mechanical oscillations or simply with time.

When using a thermoplast as a liquefiable material being provided in an inner space 2' of the central implant part, energy directors may have to be arranged on the inner surfaces of the central implant part 1 or on the surfaces of the thermoplast.

The liquefiable material of the implant according to Figs. 10 and 11 may be introduced in the central implant part 1 by the manufacturer or by the surgeon. It is introduced as any number of individual portions or it may be pressed through the sonotrode essentially continuously into the central implant part 1.

Figure 13 shows a further exemplary embodiment of the implant according to the invention. In contrast to the implants according to the preceding Figs., this implant is not designed for a load bearing function, but e.g. for releasing a therapeutically effective compound, for drainage, for electric or chemical stimulation of tissue or organs or for a similar function.

The peripheral implant part consists at least partly of the liquefiable material (surface regions 8 of the second type) and is designed as a cage having sufficient stability for implantation. The central implant part which does not have any load bearing function is arranged inside the cage. The implant is positioned in a bone cavity and the oscillation energy is applied to it by a device (sonotrode of an ultrasound device) being adapted to the proximal face of the implant. The sonotrode to be used for the implant according to Fig. 13 has the form of a hollow cylinder.

The central implant part constituting the surface regions 4 of the first type of the implant according to Fig. 13 has e.g. an osseo-integrative function and consists e.g. of highly porous calcium phosphate, of bone chips (patient's own cancellous bone) or of a gel. This central part may also be a device by which particles or molecules are released to the surrounding tissue (delivery device) or are removed from surrounding tissue (drainage device) or a stimulator,

wherein the device is e.g. designed as a correspondingly permeable container comprising walls which constitute the surface regions 4 of the first type.

The cage according to Fig. 13 may be furnished with a central implant part by the manufacturer or it may be filled with e.g. bone chips in the operating theatre. It is possible too, to implant the cage in an empty configuration and furnish it in situ with a central implant part, wherein a covering element holding the central implant part in place may be positioned and fixed by ultrasonic welding in situ also.

Figure 14 shows as a further example of the implant according to the invention an augmentation element 31, which is applicable for producing bone tissue desirable in addition to the natural bone tissue, e.g. for enlarging the ridge 32 of a jawbone. This ridge 32 and the augmentation element 31 are shown in section and in a condition after implantation. The augmentation element 31 comprises a central implant part 1 consisting of a bone growth promoting material , e.g. of a highly porous calcium phosphate. Pins of the liquefiable material are arranged in e.g. through holes (inner spaces 2') of the central implant part 1. For implantation the augmentation element 31 is positioned on the suitably prepared jawbone ridge 32, such that the pins are e.g. directed against the ridge 32. Then using a sonotrode 21 adapted to the cross section of the pins, oscillation energy is applied to the pins while the pins are pressed towards the ridge 32. Therewith the liquefiable material is at least partly liquefied and pressed into the bone tissue jawbone ridge and into the material of the augmentation element in order to fasten the augmentation element 31 pointwise to the jawbone ridge 32 and bringing the central implant part 1 (surface regions of the first type) into intensive contact with the bone tissue of the jawbone ridge, such enabling immediately after implantation infiltration of the central implant part with cells originating from the natural bone tissue for promoting bone formation. In this case, the liquefiable material is advantageously resorbable.

Figure 15A to 15C and 16A to 16C show two embodiments of the implant according to the invention, applicable for connecting two vertebrae. Again the implants comprise a central implant part 1 constituting a load bearing support 1.3 and a body 1.4 arranged inside the support and equipped for being penetrated by regenerating bone tissue. The body 1.4 consists e.g. of highly porous calcium phosphate, of bone chips or of a gel. The central implant part is adapted in form to a natural spinal disk and comprises on its upper and lower side ridges 40 extending in implantation direction A and fitting into grooves which have to be formed in the bone tissue of the vertebrae.

The peripheral implant part 2 is in the embodiment according to Figs. 15 arranged on the ridges 40 and in the embodiment according to Figs. 16 the material for the peripheral implant

part is provided in inner spaces 2' of the central implant part 1, which in the region of the ridges 40 comprises openings 20.

The implant according to Fig 15 A is pushed with a sonotrode 30 between two suitably prepared vertebrae as shown in Fig. 15B, wherein the liquefiable material of the peripheral implant part 2 is liquefied and pressed into the bone tissue of the vertebrae such anchoring the implant as shown in Fig. 15C. The sonotrode used for implantation is substantially adapted to the proximal face of the implant.

The implant according to Fig. 16A is positioned between two vertebrae as shown in Fig. 16B, e.g. using a sonotrode 30 being adapted substantially to the proximal face of the load bearing support 1.3 of the central implant part 1. When the implant is positioned, oscillation energy is applied to the liquefiable material using a sonotrode adapted to the proximal face of the inner space 2'. Therewith the material is pressed through the openings 20 and into the bone tissue of the vertebrae 41 such anchoring the implant to the vertebrae, as is shown in Fig. 16C.

The implants according to Figs 15 and 16 are fixed to the vertebrae immediately after implantation (primary stabilization). Therefore it is not necessary to stabilize the two vertebrae as known in similar prior art procedures This makes the implants particularly suitable for minimally invasive operations.